LANNDD Concept

100 KT DETECTOR FOR DUSEL

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LANNDD—a massive liquid argon detector for proton decay, supernova and solar neutrino studies and a neutrino factory detector

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Abstract

We describe a possible Liquid Argon Neutrino and Nucleon Decay Detector (LANNDD) that consists of a 70 kT magnetized liquid Argon tracking detector. The detector is being designed for the Carlsbad Underground Laboratory. The major scientific goals are:

(1) Search for $p \to K^+ + \bar{\nu}_\mu$ to 10^{35} years lifetime;
(2) Detection of large numbers of solar neutrino events and supernova events;
(3) Study of atmospheric neutrinos;
(4) Use as Far detector for Neutrino Factories in the USA, Japan or Europe.

PACS: 29.40; 96.60.J; 95.85.R; 14.20.D; 14.60.P

Keywords: Neutrino; Nucleon decay; Liquid argon

1. Introduction

One option for next generation nucleon decay search instrument is a fine-grained detector, which can resolve kaons as well as background from cosmic ray neutrinos that are below the threshold for water Cerenkov detectors such as Super-Kamiokande (SK). One option for a next generation nucleon decay search instrument is a fine-grained detector, which can resolve kaons as well as background from cosmic ray neutrinos that are below the threshold for water Cerenkov detectors such as Super-Kamiokande (SK). Such a detector can make progress beyond the *few* × 10^{33} yr limits from SK for SUSY favored modes because the reach improves linearly with the time and not as

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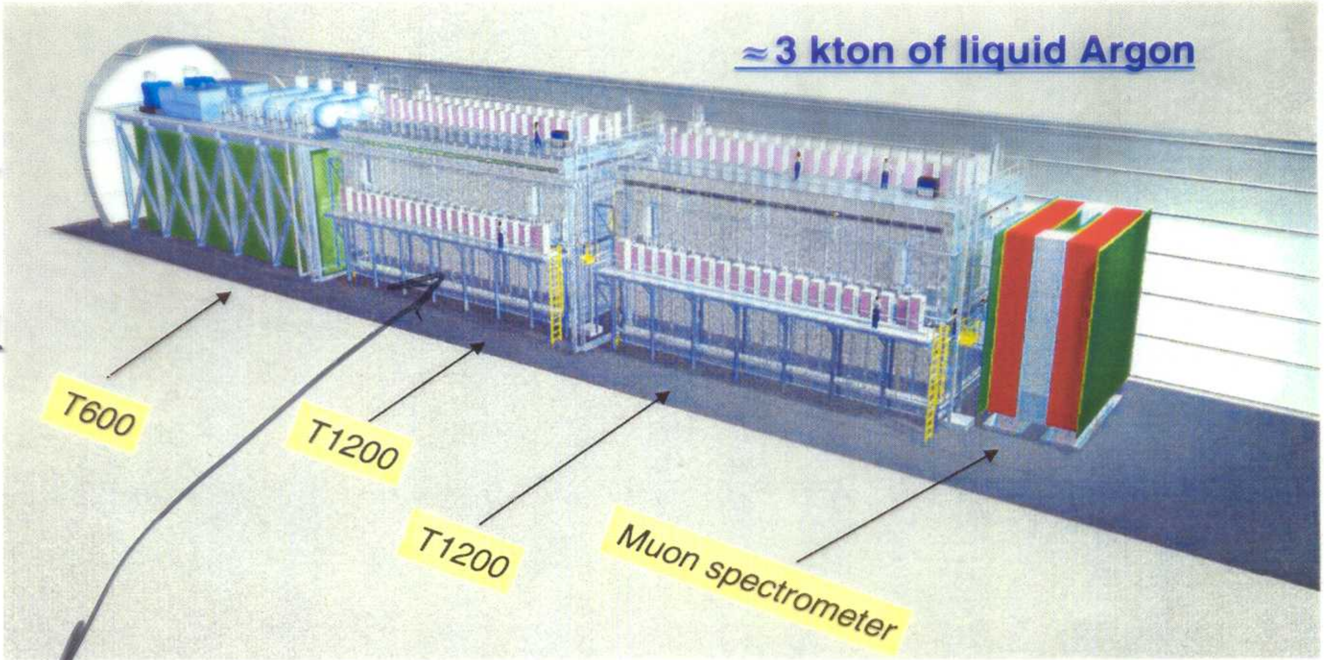
T600 movement
~Pavia

ICARUS T3000: "A Second-Generation Proton Decay Experiment and Neutrino Observatory at the Gran Sasso Laboratory"

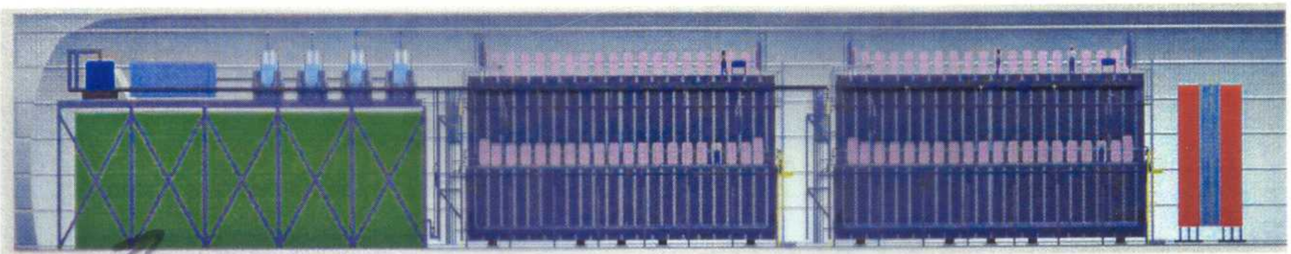


UNDER CONSTRUCTION
T600 → LNGS Nov 2004
T1200 Funded

10 M Euros NOW for T1200 Dewars + Structure Now

ICARUS detector configuration in LNGS Hall B (T3000)

First Unit T600 + Auxiliary Equipment	T1200 Unit (two T600 superimposed)	T1200 Unit (two T600 superimposed)	Magnet



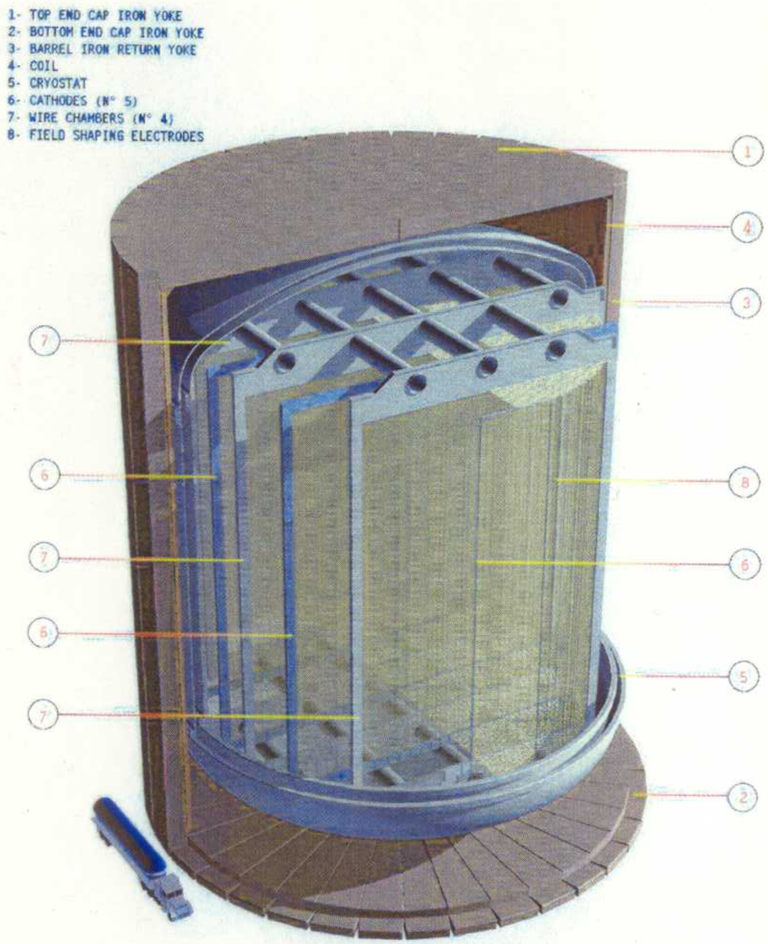
≈ 35 Metres ≈ 60 Metres

600 Ton – Move to LGNS Nov/Dec 04

(final co-location of magnet not yet finalized)

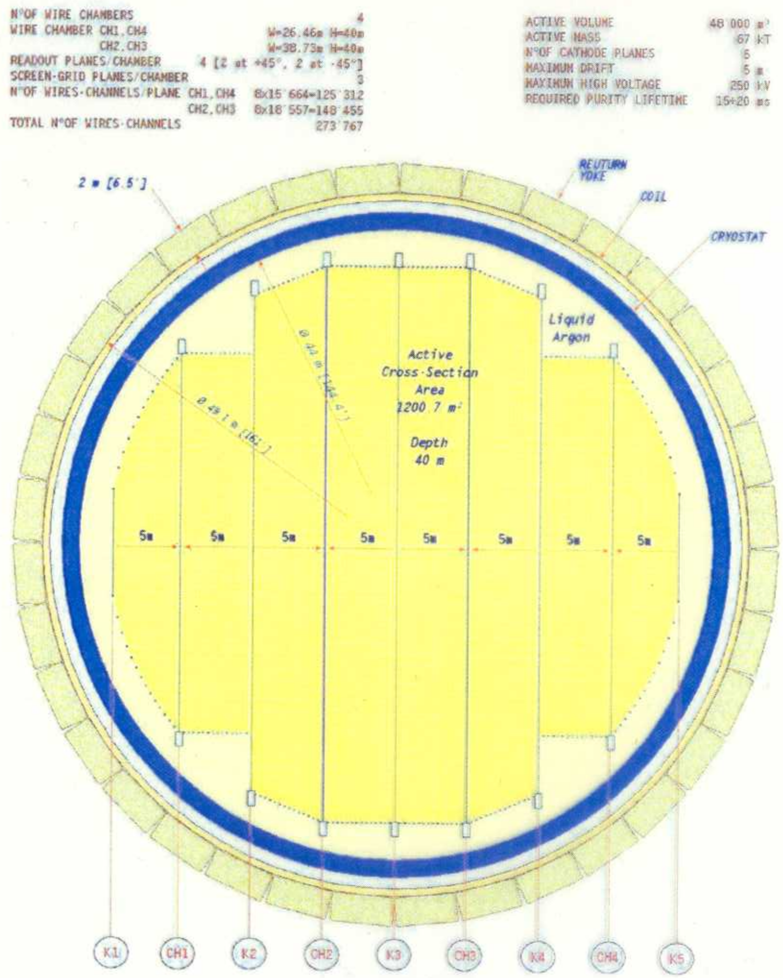
LANNDD – 100 kton Liquid Argon Neutrino and Nucleon Decay Detector

(astro-ph/0105442, Nucl. Instr. and Meth. A503, 136 (2003))



LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector

F. Sergiampietri-August 2000



LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector
Horizontal Cross-Section

F. Sergiampietri-August 2000

Max drift length of 5 m (limited by O_2 purity), ⇒ Several drift cells.

Proton Decay Search

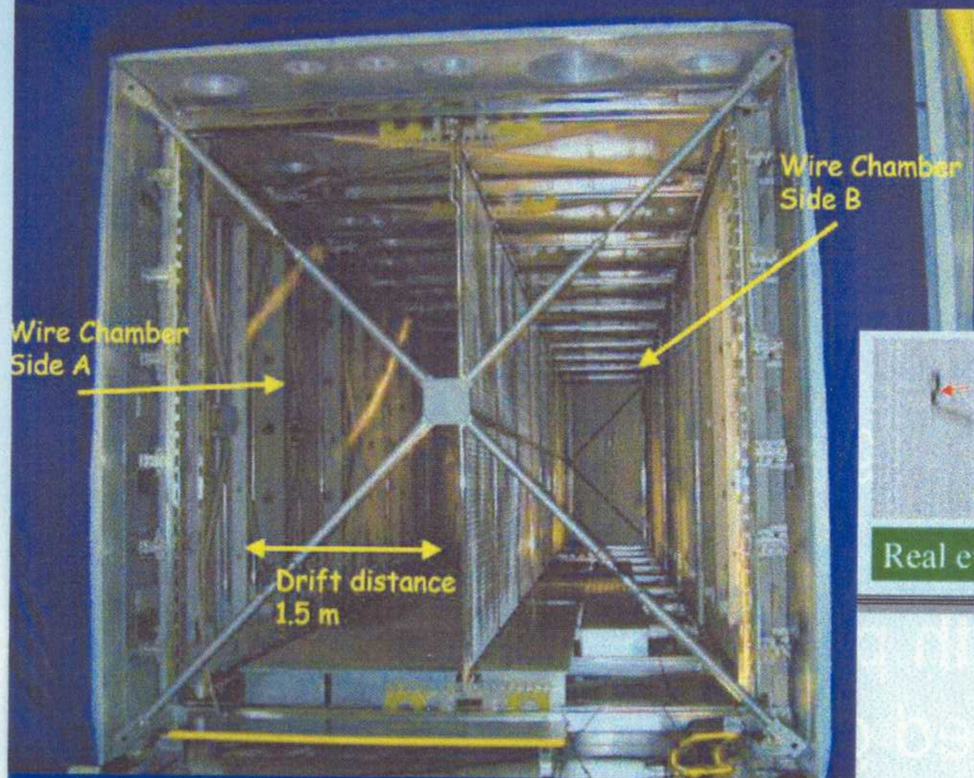
Limits on proton mean life (τ_p)

Exposure: 300 kTon × year				
4.5 years @ LANNDD	$p \to e^+ \pi^0$		$p \to K^+ \bar{\nu}$	
	Efficiency (%)	τ_p (years)	Efficiency (%)	τ_p (years)
No nuclear reinteractions	42	1.5×10^{34}	85	3.1×10^{34}
Nuclear reinteractions (FLUKA)	19	6.8×10^{33}	85	3.1×10^{34}

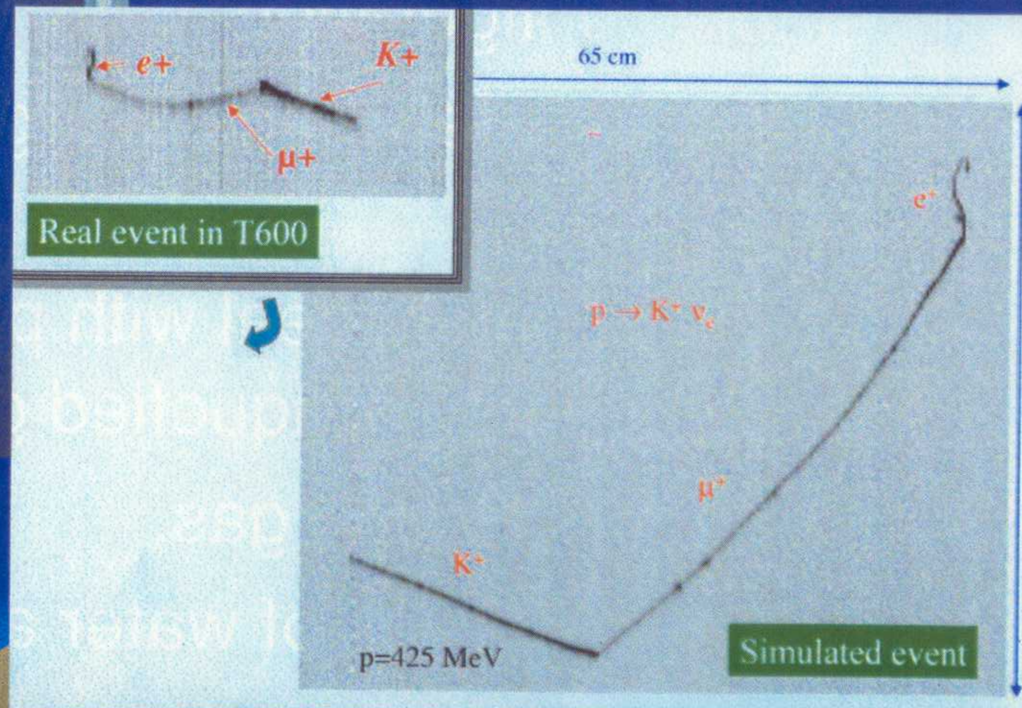
Exposure: 1000 kTon × year				
15 years @ LANNDD	$p \to e^+ \pi^0$		$p \to K^+ \bar{\nu}$	
	Efficiency (%)	τ_p (years)	Efficiency (%)	τ_p (years)
No nuclear reinteractions	42	1.5×10^{34}	85	1×10^{35}
Nuclear reinteractions (FLUKA)	19	2.3×10^{34}	85	1×10^{35}

A

600T Module



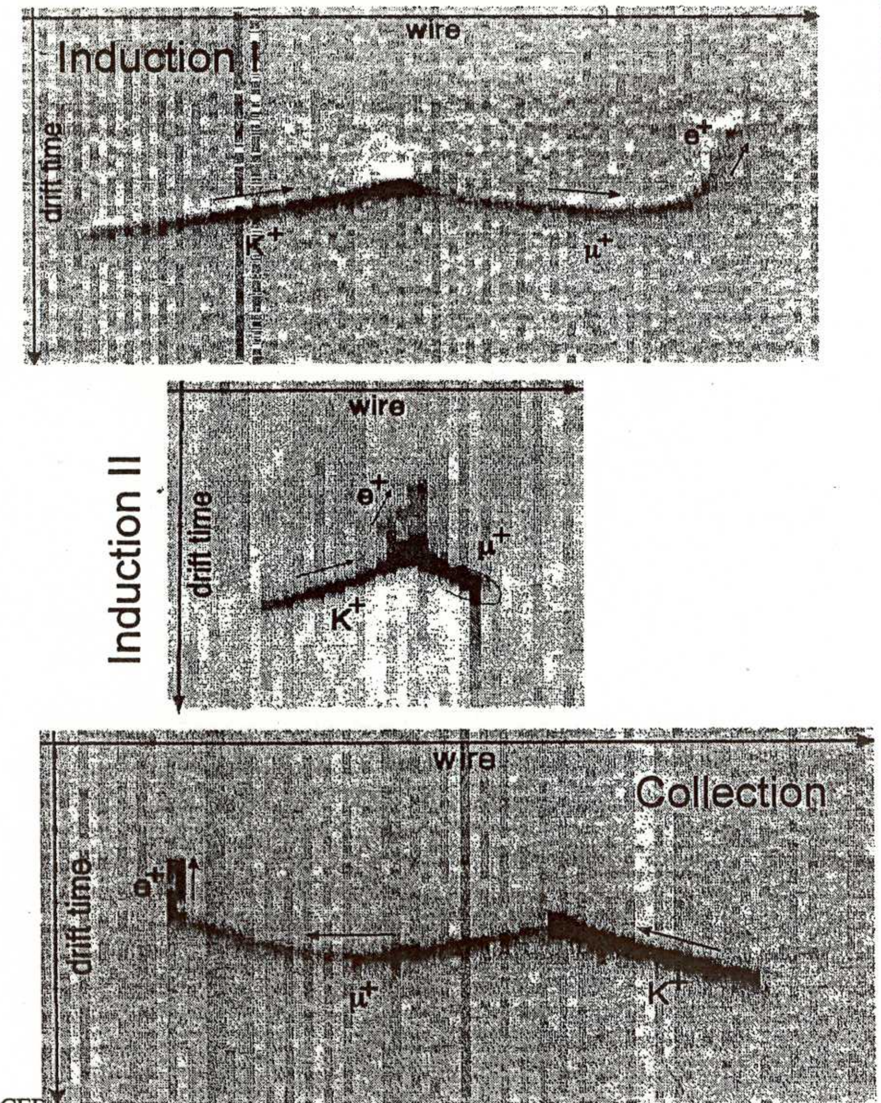
K⁺ **REALLY** visible in Liquid Argon
⇒K⁺ modes efficiency ~ 10 times that of water Cherenkov.



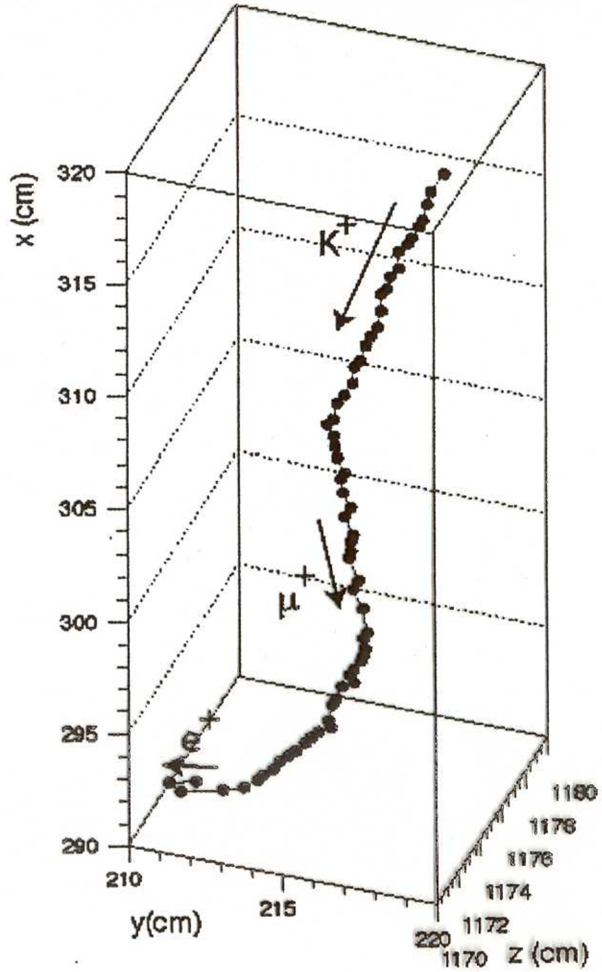
Installation and operation at LNGS 2004-2005

T600 at Pavia

Kaon decay candidate

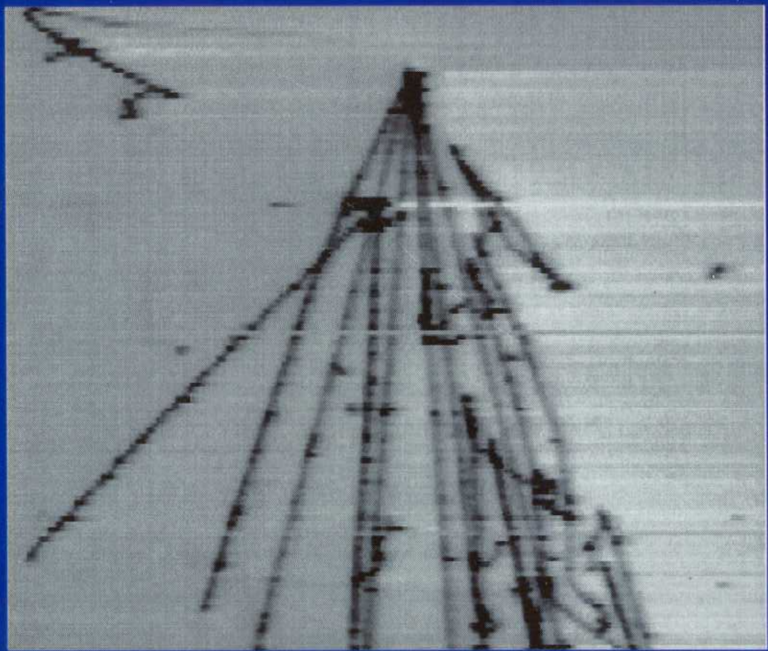


Run 939 Event 46 Left chamber



— Some Real Events —

50 l prototype in the CERN WANF neutrino beam



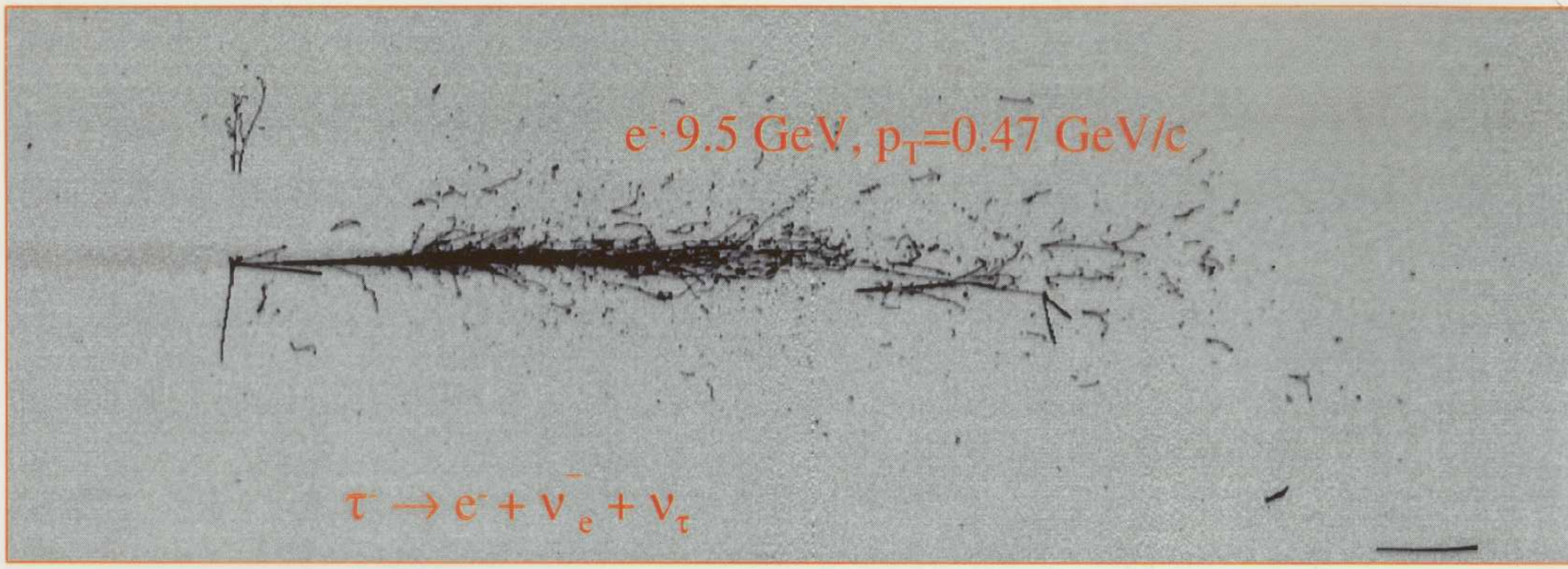
$\nu_\mu + X \rightarrow \mu^- + many \quad prongs$

$\nu_\mu + n \rightarrow \mu^- + p$

CNGS ν_τ interaction, E_ν=18.7 GeV

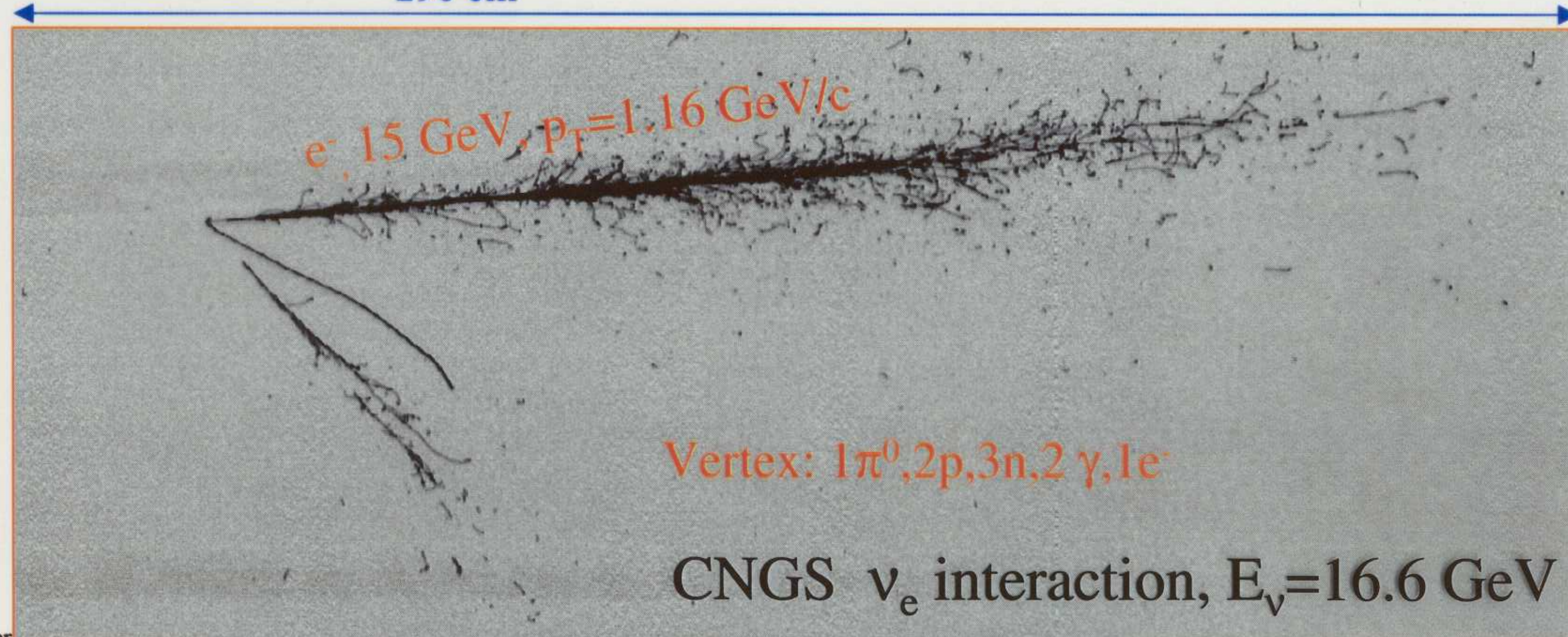
280 cm

105 cm



290 cm

120 cm

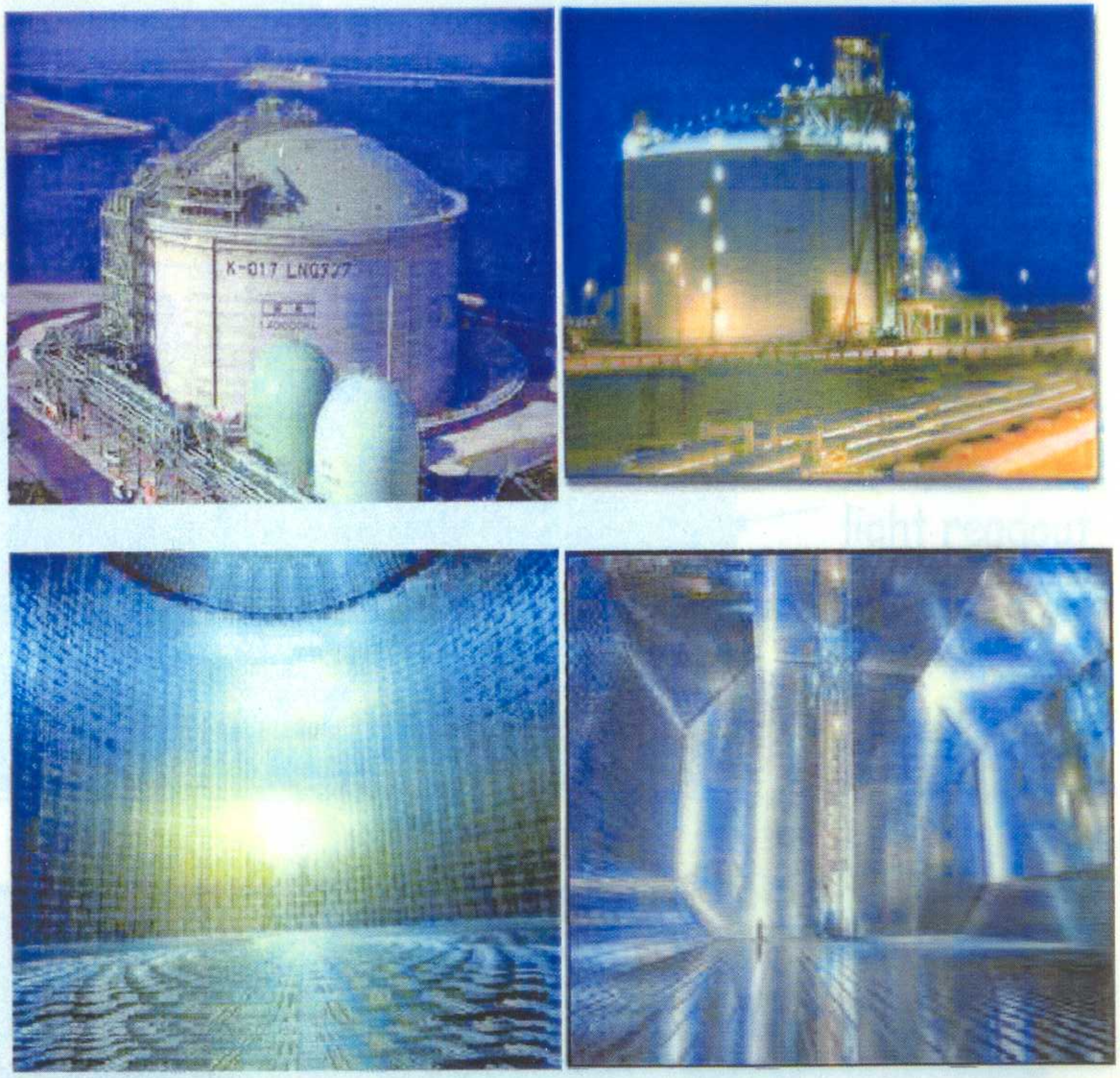


POWERFUL REJECTION OF π^0's

An effective alternative: a very massive LAr detector

- Can one extrapolate LAr technology to > 100 kton detector ?
- Ultra-pure liquid Argon is cheap and industrially available.
- Cryogenic tanks for Liquefied Natural Gas (LNG) are industrially well developed products with considerable sizes. Heat leaks are small (~ 5 W/m^2)
- Ideas being developed:

See e.g.:



Experiments for CP violation: a giant liquid Argon scintillation, Cerenkov and charge imaging experiment.

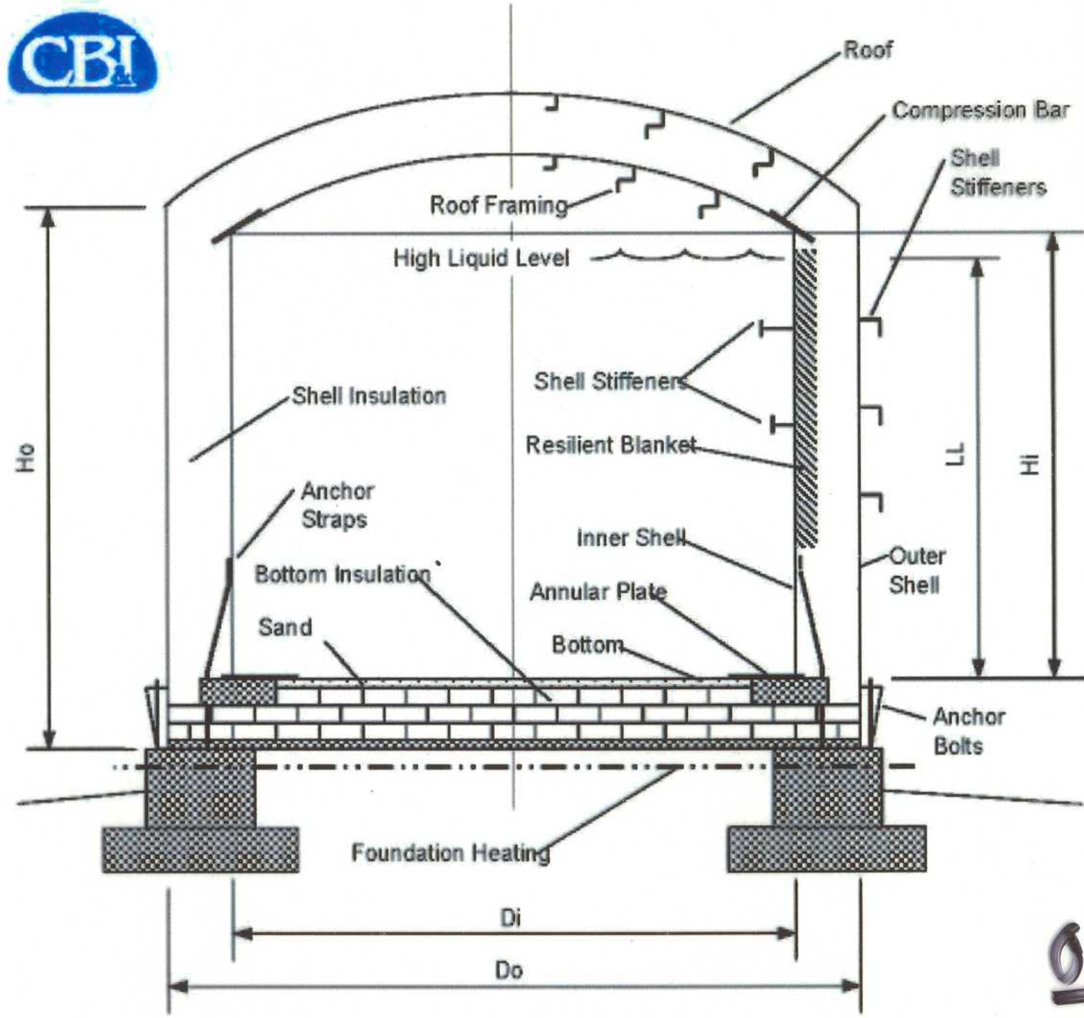
A.Rubbia, Proc. II Int. Workshop on Neutrinos in Venice, 2003, hep-ph/0402110

Liquid Argon Imaging Technology.

C.Rubbia, talk at the SLAC Experimental Seminar February 17, 2004.

200-kton Cryogenic Tanks Used for LNG Storage

Appendix D



Double Wall & Double Roof Tank

	Feet
Di =	165
Hi =	117.9803
LL =	117.7303
Do =	173
Ho =	118.0443

100k Ton

Estimated Cost ~150 M $

ON SURFACE

Chicago Bridge & Iron: can build 100-kton LAr tank for < \$20M.

5.2.4. LANNDD

The Liquid Argon Neutrino and Nucleon Decay Detector (LANNDD) is a concept for a large liquid argon drift chamber in the 100-kton range. Such a detector would have very good track and vertex resolution (few mm) compared to water

Cherenkov detectors (10's of cm). It could be realized by scaling up the design of the existing ICARUS 600-ton modules to longer drift distances and larger module volumes.

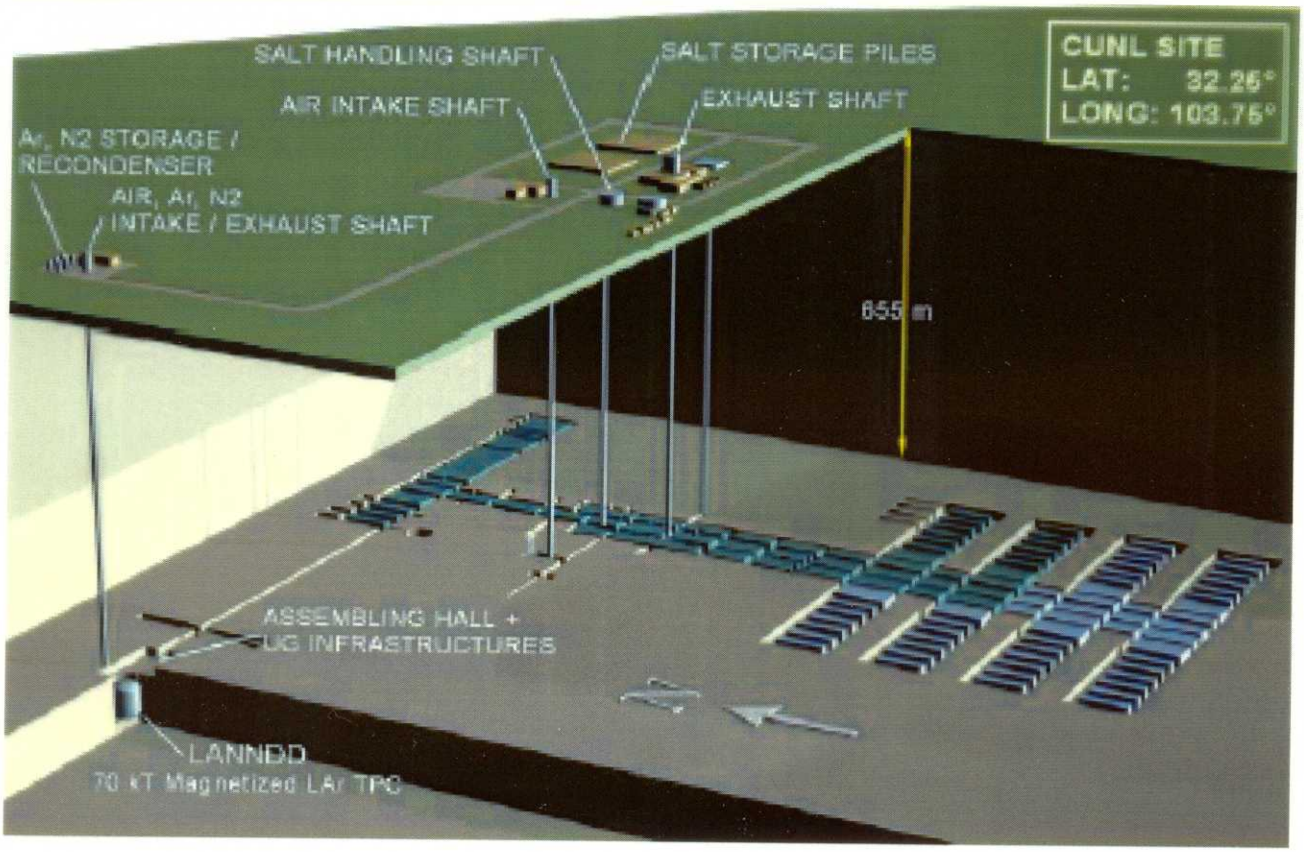
The potential capabilities of a liquid argon detector cover a wide range of physics applications. In long-baseline neutrino-oscillation experiments such as T2K and NOνA, a crucial limitation in searching for ν_e appearance is the capability to discriminate neutral-current originated π^0 initiated showers from those initiated by the physically interesting quasi-elastic ν_e interactions. Since Compton scattering lengths are typically 10's of cm in common materials, liquid argon would be able to cleanly separate vertices even at higher energies (where the π^0-decay gammas are close to collinear) and hence discern π^0 from anti-ν_e induced events. The potential gain in sensitivity over other technologies could be as much as an order of magnitude. Thus a LANNDD-type detector, if technically feasible, might be a very desirable alternative for a future generation "superbeam" or neutrino factory long-baseline experiment.

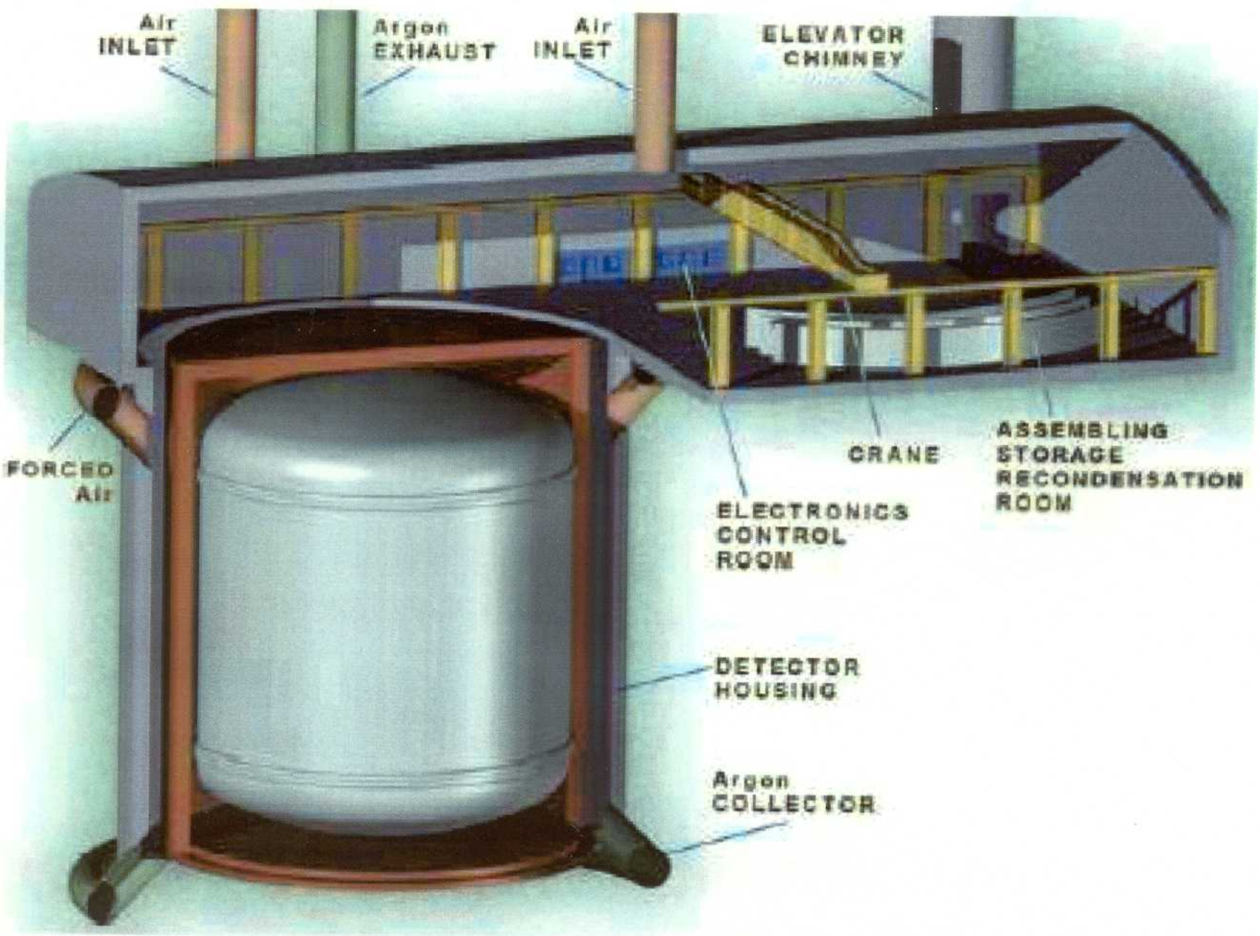
In addition, there are potential improvements in sensitivity in the search for proton decay. For some important modes (such as $p \rightarrow K^+\nu$), the daughter particles are below the water Cherenkov threshold and hence a traditional large-water detector has low sensitivity. In contrast, a liquid argon detector would observe these particles. Also the detection of ν_e's from galactic and relic supernovae, via the charged-current interaction with argon ($\nu_e + {}^{40}Ar \rightarrow {}^{40}K^* + e^-$), would be better in liquid argon.

SAGENAP believes that liquid argon detectors have an important role to play in future neutrino experiments and could make substantial contributions to the effectiveness of a neutrino factory and in the search for proton decay. Although the U.S. made significant contributions in the initial stages of the development of this technology in the 1980's, presently it makes only a secondary contribution as nearly all effort now takes place in Europe. The sub-panel recommends that the U.S. regain technical strength in liquid argon detector technology as potentially very important to the field of neutrino physics and underground science over the next few decades. The sub-panel supports the idea of an R&D effort to build a 5-m test chamber to investigate the technical feasibility of a large-volume liquid argon detector, but with the following reservations: (1) the safety of kiloton volumes of liquid argon in an underground chamber has not yet been established to levels required by WIPP or any other national laboratory, and (2) the current group proposing the prototype drift volume is far too small and over-committed to other projects to carry out such a major R&D effort. *

We encourage the LANNDD group to participate in the formation of a dedicated research team of sufficient size and technical expertise to develop a proposal to undertake a major R&D effort in this important area.

STUDY OF LANNDD AT WIPP SITE





FYI:

Requirements for the LANNDD Detector at DUSEL

David Cline and Franco Sergiampietri
UCLA / PISA

Information sent to Homestake, WIPP, Icicle Creek .... for S2 proposals

DUSEL STUDY INPUT TO LARGE MODULE GROUPS

- Depth - 2000 MWE or greater
- Total active volume: 50'000 m3
- Total active mass: 69.5 kTon
- Active volume height: 40.5 m
- Active volume diameter: 40.5 m
- Max drift: 5.1 m
- Fiducial volume: 41.4 m3
- Number of channels: 196'000
- Total LAr volume: 60'000 m3
- Total LAr surface: 17'100 m2
- Heat input by radiation (double wall cryostat, vacuum insulated, 40 superinsulation layers -> 0.5 W/m2): 5.1 kW
- Heat input by conduction (cables, mechanical supports): 25 kW
- Total LN2 consumption: 9.2 m3 (liquid)/day.
- Electronics on the detector (about 680 crates for analog and digital processing electronics): ~250 KW
- Counting room + remote electronics + UPS's + air conditioning: ~40 KW
- Pumping system for the insulation vacuum: ~50 KW
- LAr/GAr purification and circulation: ~20 KW
- Underground hall ventilation/air conditioning: ~40 KW
- Underground mechanical workshop and crane: ~30 KW
- Air intake/Ar exhaust fans: ~20 KW

Collaboration:

C. Cerri, F. Sergiampietri, R. Pazzi
INFN – Sezione di Pisa

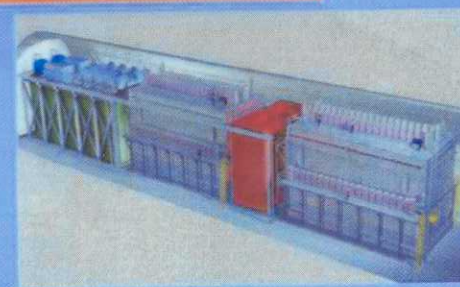
D.B. Cline, Y. Seo, X. Yang, H. Wang
UCLA – Department of Physics and Astronomy

A. Bueno, S. Navas, 5 students
Universidad de Granada
Departamento de Física Teórica y del Cosmos – Física de Altas Energías

Laboratories where the detector/tests are made:

INFN-Sezione di Pisa
UCLA
Università di Granada
CERN

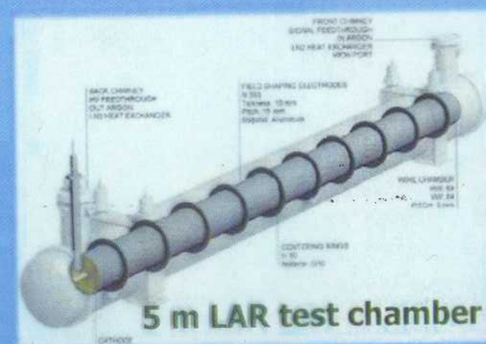
Neutrino Heads-Ups



ICARUS Concept

- ICARUS:
  - Planned 3-kton Liquid-Ar TPC. 600T exists.
  - N decay, ν physics (incl. ν beam from CERN)

→ We support the physics goals. U.S. contribution should be continued, in co-ordination with actual detector schedule.

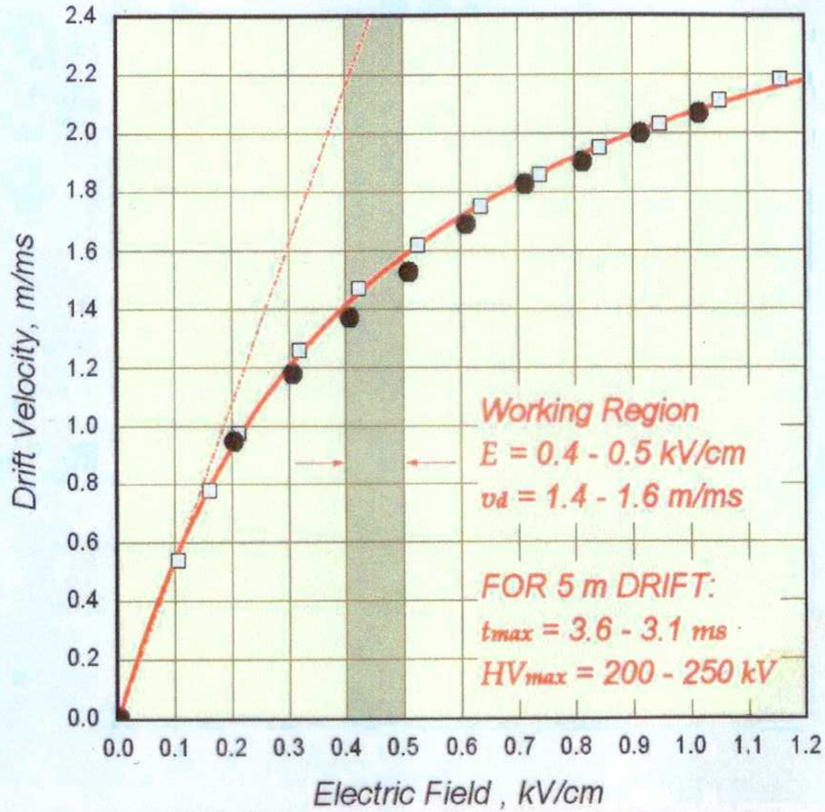


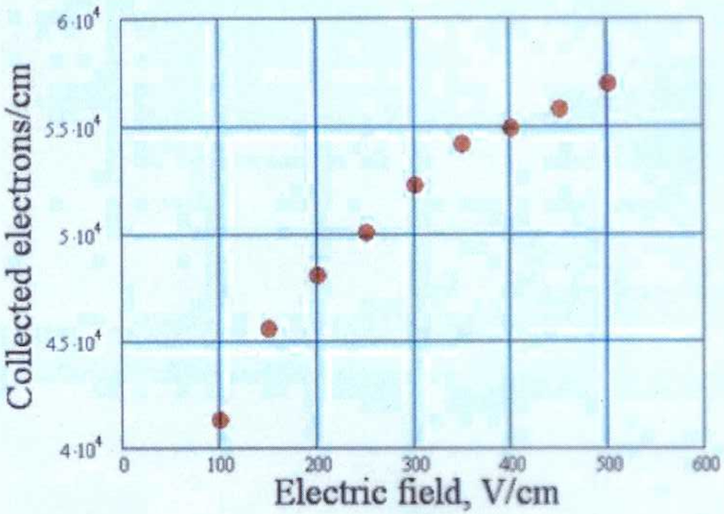
5 m LAR test chamber

- LANNDD:
  - Concept for Liquid-Ar detector in 100-kton range.
  - N decay, long-baseline ν, supernova ν.

→ Liquid-Ar detectors have important role to play in future ν experiments. U.S. should regain technical strength. Support the idea of an increased R&D effort, subject to safety consideration & requiring a strong group.

High voltage, drift velocity and collectable charge



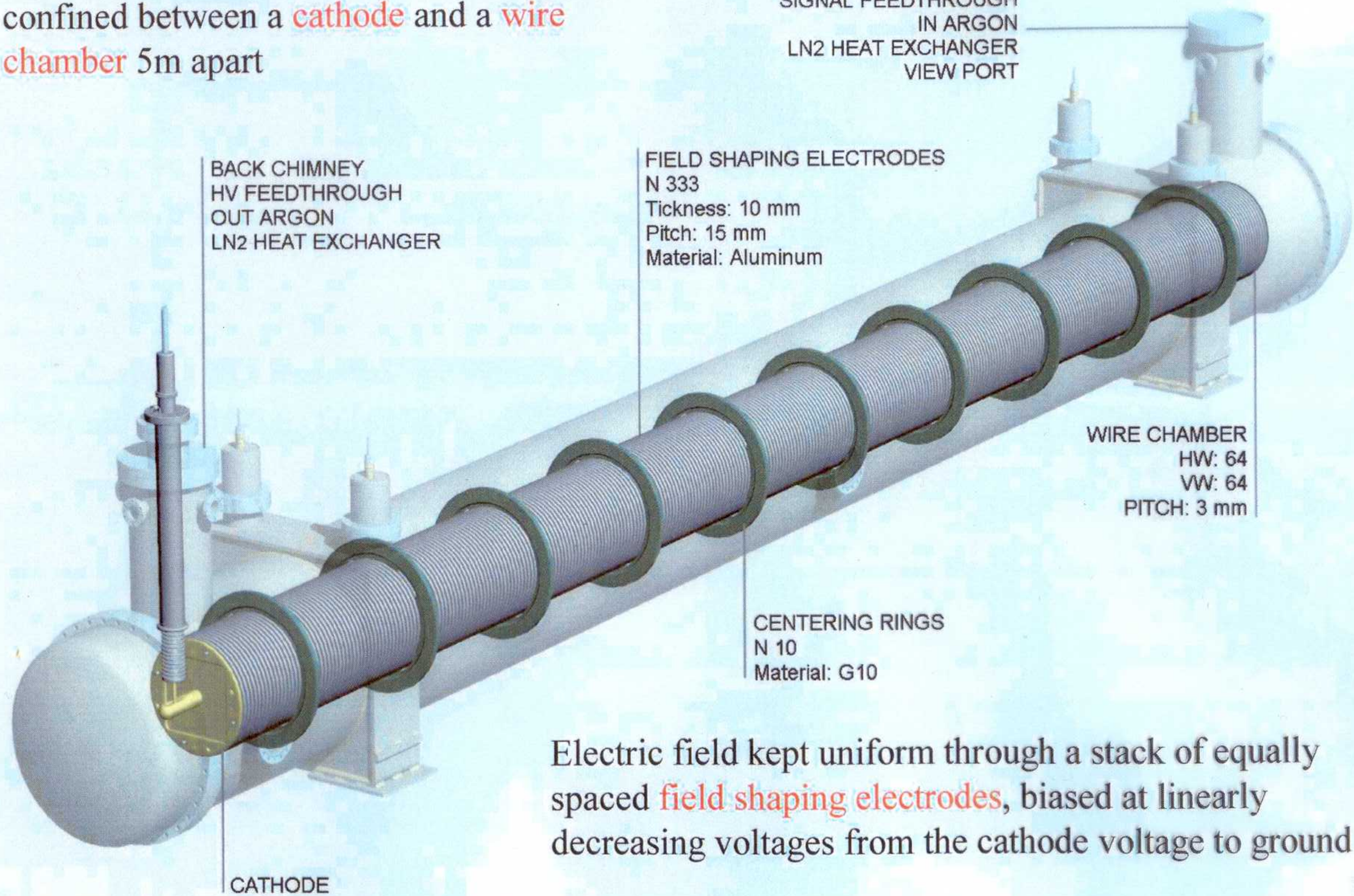


High voltages in the range $V_d \sim 200 - 400\ kV$

For $E = 0.5\ kV/cm$ and $d = 5\ m$, the maximum drift time is $T_d = 3.1\ ms$

The detector

TPC with parallelepiped drift volume confined between a cathode and a wire chamber 5m apart



Electric field kept uniform through a stack of equally spaced field shaping electrodes, biased at linearly decreasing voltages from the cathode voltage to ground

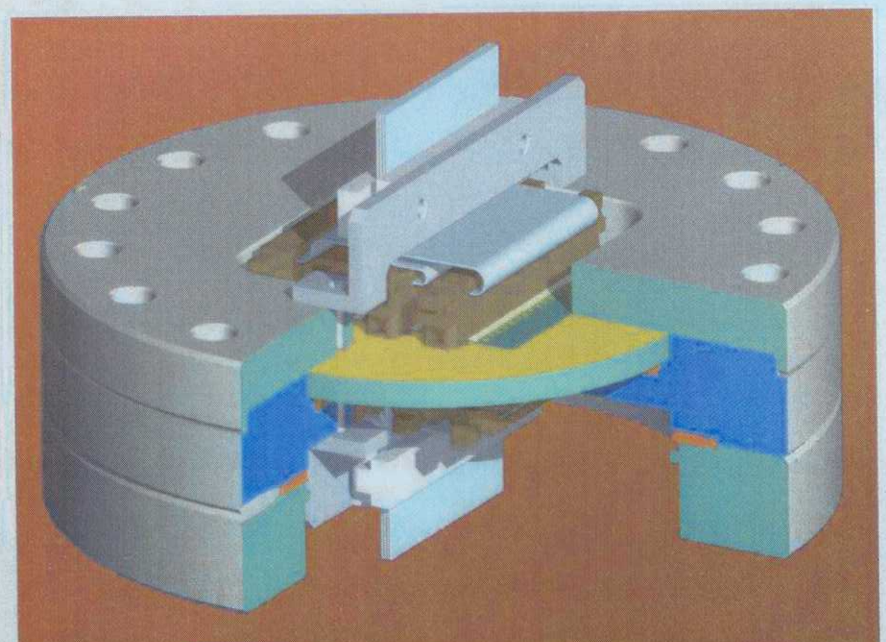
The wire chamber

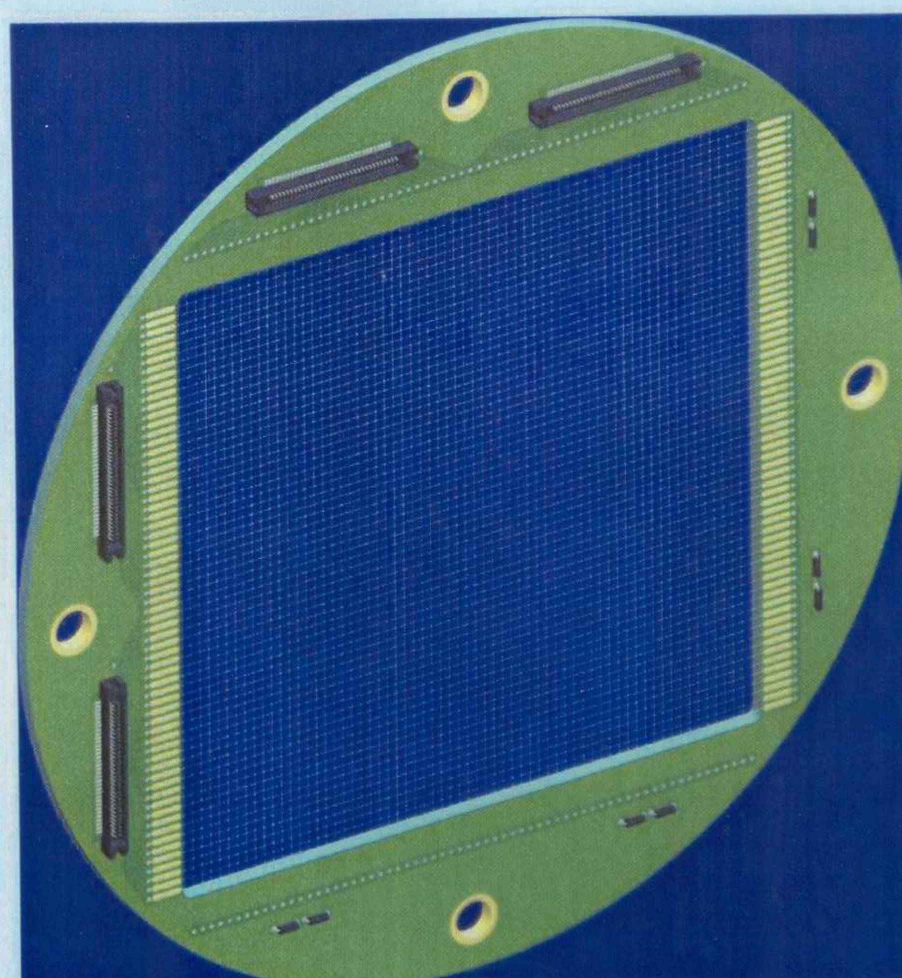
Two wire planes:

1st plane: 64 horizontal wires, 3 mm pitch, working at ground (as Fisher grid) or as induction plane for the vertical coordinate.

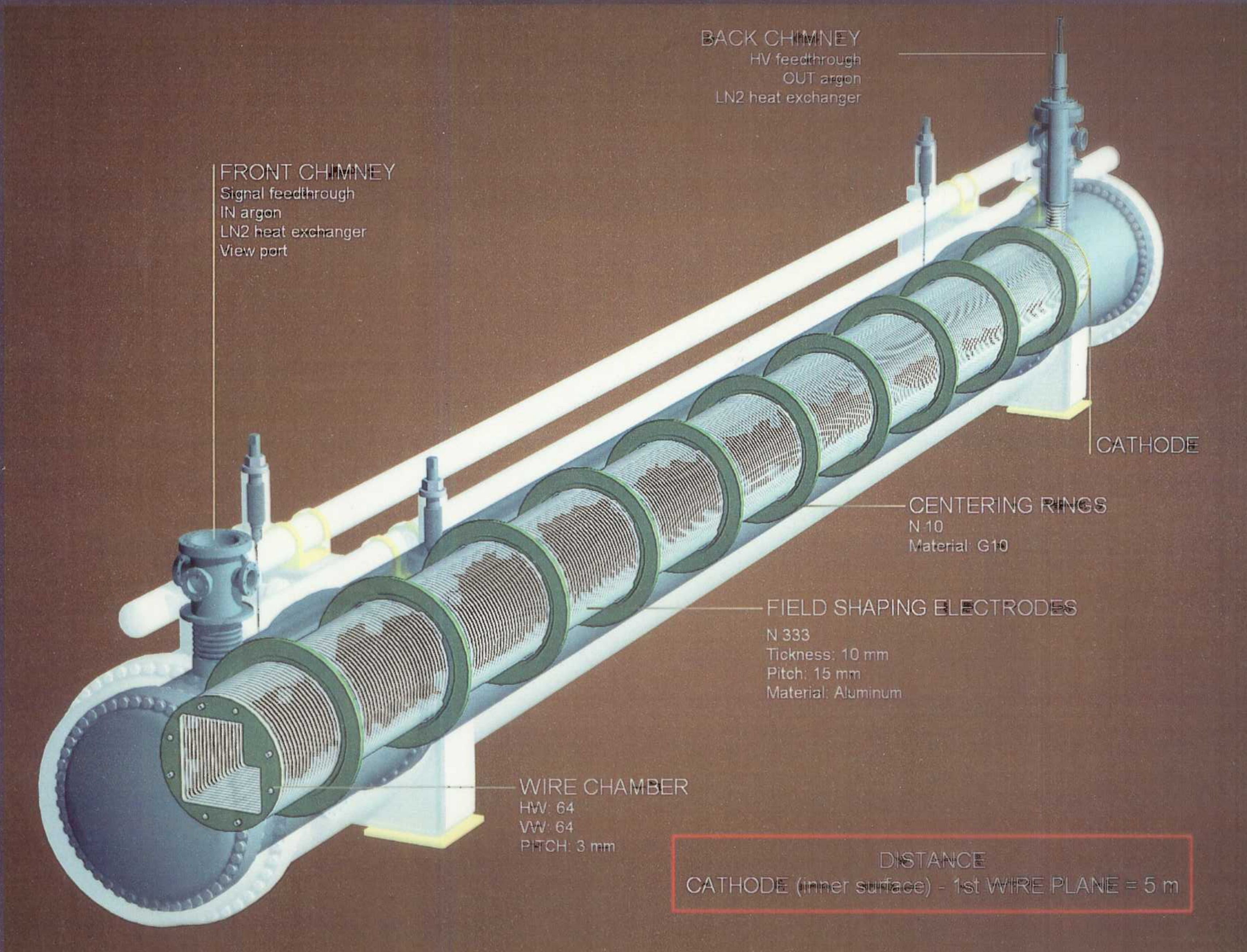
2nd plane: 64 vertical wires, 3 mm pitch, working as collection.

128 wires directly connected to a signal feedthrough and from there to the outer read out electronics (charge and current sensitive preamplifiers, amplifiers, ADC's)





5 m drift liquid argon TPC – Inner detector



Experimental methods - 1

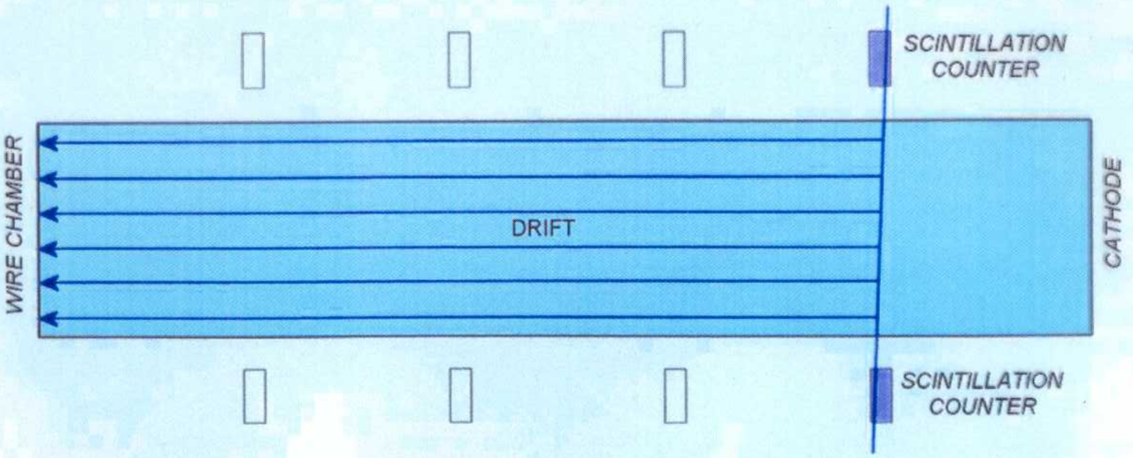
Recording of vertical cosmic-ray induced tracks, selected by an outer plastic scintillator telescope at different distances from the wire chamber.

During the reconstruction the track image is searched in a time windows corresponding to the telescope position.

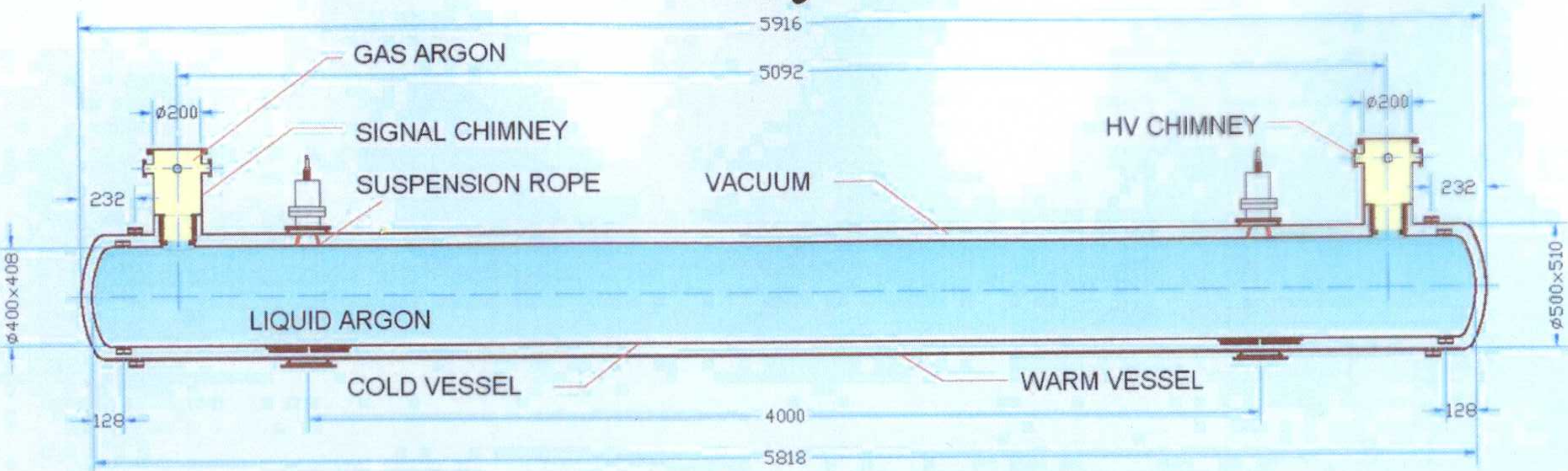
The attenuation along the drift path is evaluated from the dependence of the pulse heights on the telescope position.

The longitudinal diffusion is measured from the time behavior of the signals.

The side diffusion is reconstructed in the plane of vertical wires, on the basis of the pulses induced on the wires next the one mainly interested by the track.



The cryostat



Double wall, vacuum insulated cryostat.

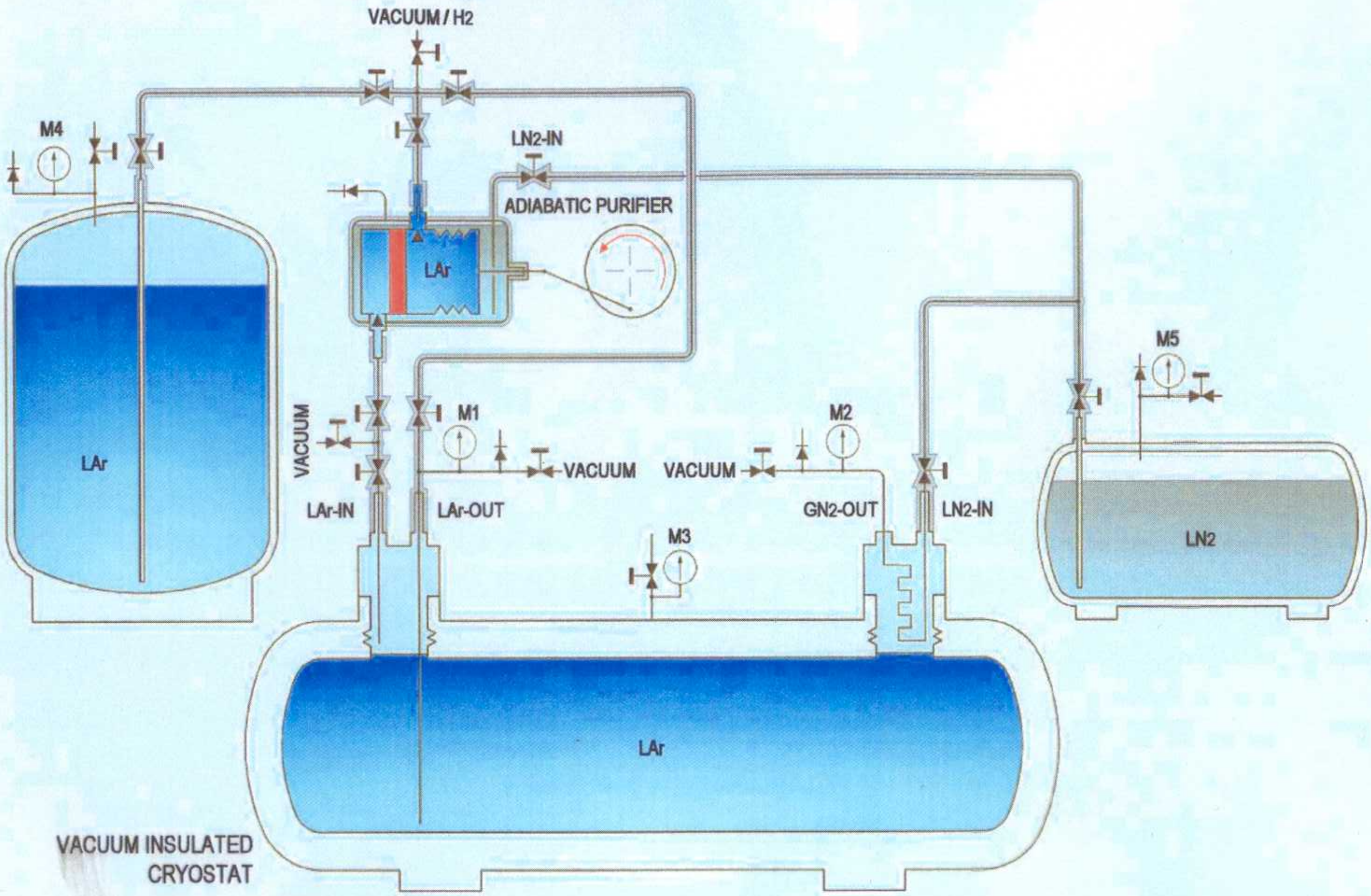
Inner cold cylinder ($D = 400\,mm \times L = 5.8\,m$) hanging from the outer warm cylinder by stainless steel (or Kevlar) ropes.

Two chimneys ($D = 200\,mm$) positioned at the two ends ($d = 5.1\,m$), used for *a)* signal and control feedthrough, 1st heat exchanger, argon input/output and *b)* high voltage feedthrough, 2nd heat exchanger.

Chimney's volume used as argon expansion buffer (~ 2% of the liquid volume).

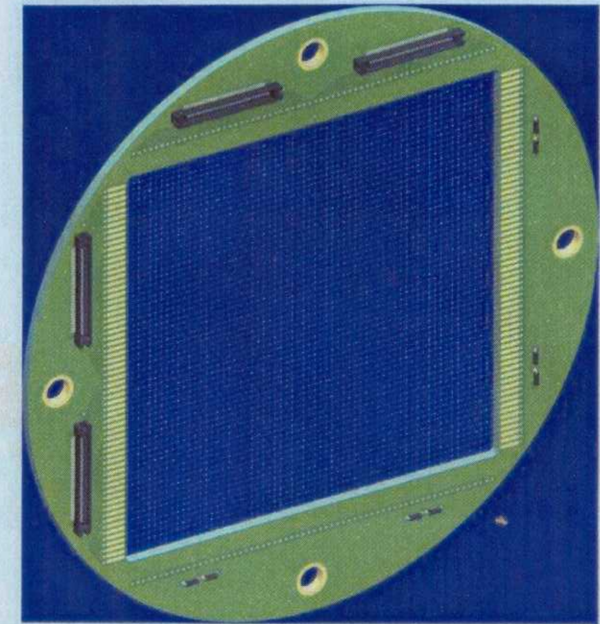
Heat input (including conduction through signal cables and HV feedthrough) reduced to few watts (due to hanging system, warm/cold mechanical connection via stainless steel diaphragm bellows, super-insulation wrapping of the cold cylinder). Foreseen LN_2 consumption < 10 *l/24h*.

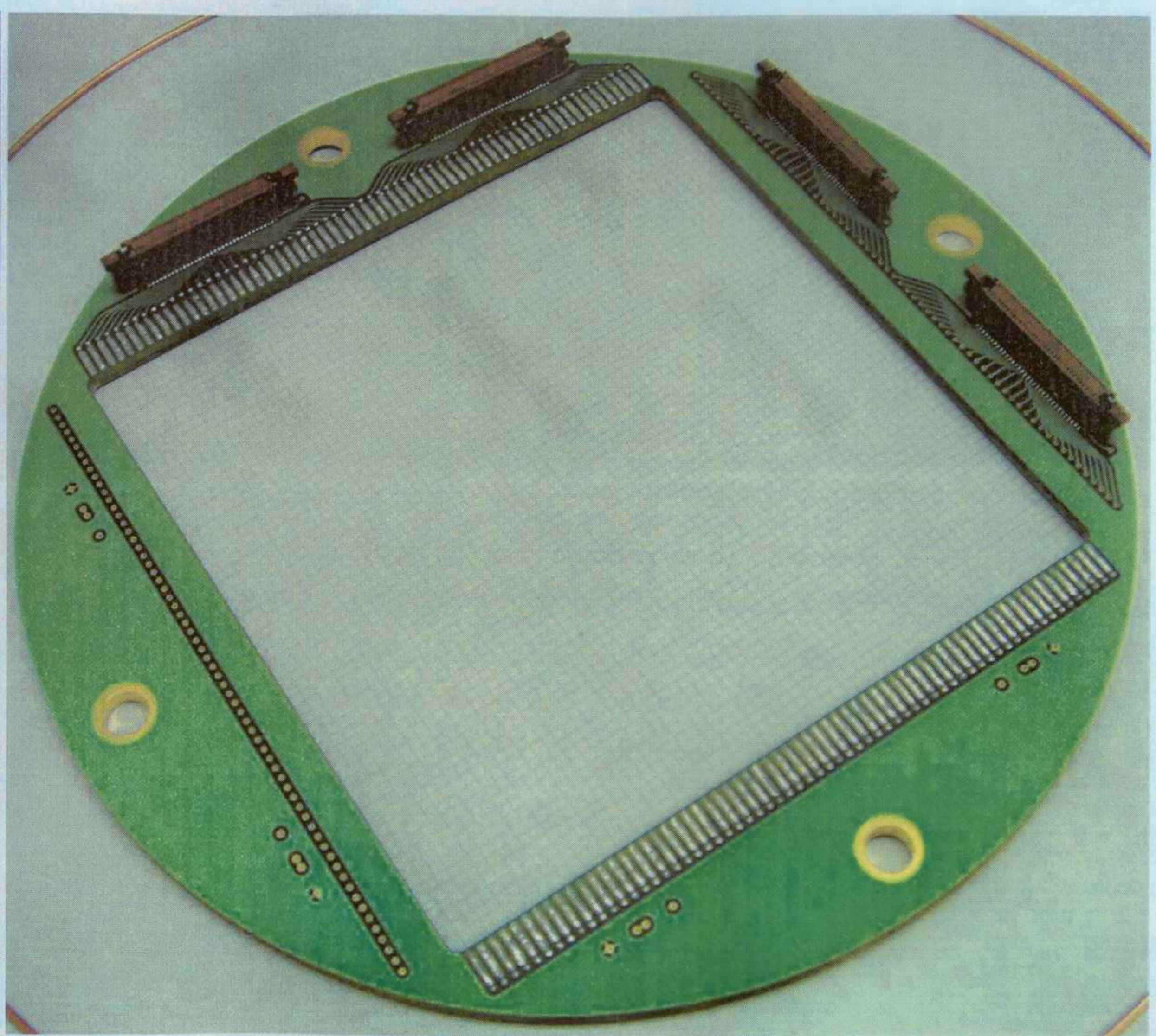
Cryogenic connections



- Liquid argon and nitrogen tanks
- Liquid (and gaseous) phase re-circulation purifier with integrated cryogenic pump
- Vacuum measuring heads, over-pressure check valves, break disks, heat exchangers
- Level, temperature, pressure meters and purity monitors.

Progresses: The wire chamber





Progresses: The wire seal cold flanges

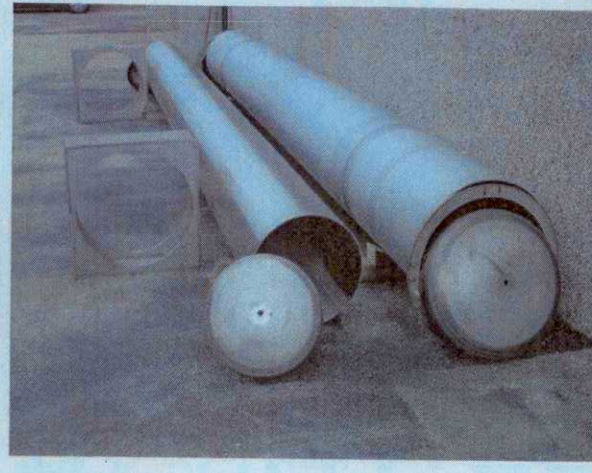
New design seal

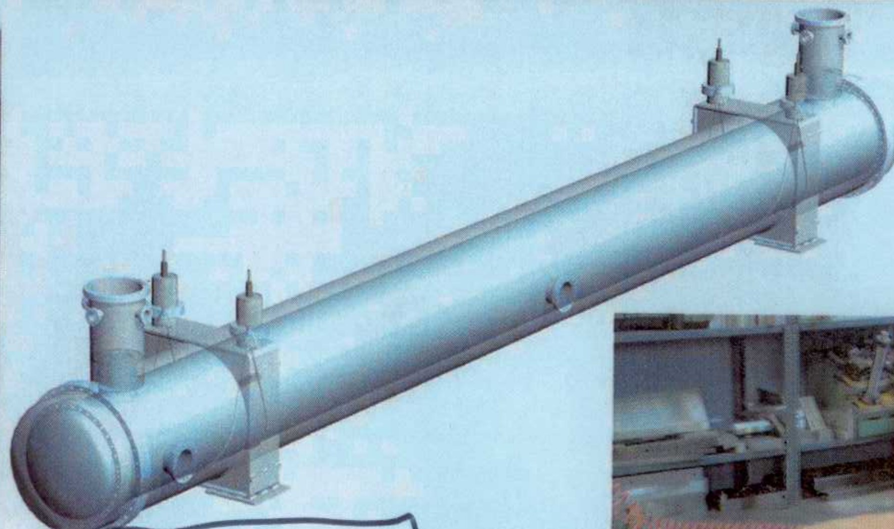
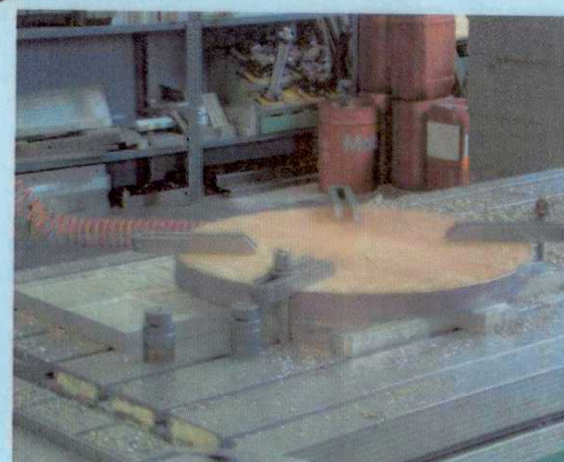
Tightness tested at CERN Cryolab with Helium leak detector at temperatures between 300°K and 4°K, with/without overpressures up to 3 bars

Detector parameters

Drift volume dimensions	$H = 192 \times W = 192 \times L = 5010\ mm^3$
Number of field electrodes	333
Wire chamber dimensions	$h = 196 \times w = 196\ mm^2$
Wire pitch	$p = 3\ mm$
Number of wire planes	2
Number of wires in plane 1 (induction/grid)	64
Number of wires in plane 2 (collection)	64
Distance between wire planes	$5\ mm$
Pitch of the field electrodes	$15\ mm$
High voltage (for $E_{drift} = 0.5\ kV/cm$)	$250\ kV$
Maximum drift time (for $E_{drift} = 0.5\ kV/cm$)	$3.14\ ms$
Required lifetime for attenuation < 20% after 5m	$14.06\ ms$
Required argon purity for attenuation < 20% after 5m	$0.02\ ppbO_2$

Progresses: The cryostat

Machining the different components FINISHED

PLAN: - ASSEMBLE AT PISA/CERN ~2005
Tests ~2005
Could be moved to USA ~2006